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MAPPING ALPINE SOILS USING COLOR POSITIVE AND COLOR INFRARED PHOTOGRAPHS

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I. ABSTRACT

During a soil survey of the Indian Peaks area of the Colorado Front Range, it was found that large scale color positive photographs taken in the autumn were extremely useful for mapping alpine soils. Smaller scale color infrared photos were also helpful for delineation of mapping units. The soil mapping units were deduced on the basis of landforms and snow accumulation which is reflected in patterns of vegetational communities.

II. INTRODUCTION

In the mountains, the area above treeline is called the alpine belt or zone. In spite of the relative severity of the alpine environment in terms of temperature and wind, this ecosystem is "fragile" only in the presence of human use of the land because of a low capacity to sustain the impacts of man.¹ Only a few mountain regions of the world, particularly those in polar regions, have escaped severe damage by human activity. As the human population increases, man is moving more and more into the mountains increasing pressure on the alpine ecosystem through grazing, mining, and recreational activities.

In order to control and minimize man's impact on the beautiful alpine environment, more land-use planning of this region is needed. At this time, however, there are very few land-use plans available for the mountainous regions of the world. One avenue towards meeting this demand is through the use of soil surveys which can serve as extremely valuable tools for planners. Man's increasing pressure on mountainous areas dictates the need for better and more rapid methods of delineating soil differences in order to produce more effective land use and management plans.

An inherent problem in the realization of soil information is the logistical difficulty and expense of soil surveys conducted above treeline. Because there is limited access by motorized transport, hiking is the main mode of reaching these areas. In addition, the soils are extremely rocky

so that excavation of pits requires considerable lengths of time. The field season is very short and continuously interrupted by periods of bad weather. The encouraged use of aerial imagery to help render soil surveys more economical and the elaboration of this method is the focus of this paper.

A 57,000 hectare soil survey was recently completed in the Indian Peaks region of the Colorado Front Range, U.S.A.. Approximately 15,000 hectares of the research area lies above treeline. It was mapped as a third order soil survey at the 1:24,000 scale. The soil survey was conducted with the aid of the Soil Conservation Service. The mapping project was conducted as part of a project to compile an environmental atlas of the Indian Peaks region of the Colorado Front Range which also produced 13 additional thematic maps of the area in various disciplines.²

This entire project was supported by a NASA research grant, and one aim of the soil mapping portion included the evaluation of using aerial photography to conduct soil surveys in high mountainous areas. It was found that certain types of photographs especially color positive photographs taken in the autumn, can provide excellent data for producing soil maps of alpine areas. The same photographs, though, were less useful for mapping subalpine soils for it is difficult to differentiate forest types on many of the photographs.

III. PRODUCTION OF THE INDIAN PEAKS SOIL MAP: SUCCESSION OF WORK

Derivation of the soil map legend was by far the most difficult and time consuming part of the project. In this first step, approximately 185 soil pits were dug and profiles were described in each vegetational community as defined by Komarkova³, parent material, and topographic position in the alpine, for it was felt that these factors would produce the main differences in the soils. Soils were classified to the subgroup level of USDA Soil Taxonomy⁴. The final soil profiles were field checked by representatives of the USDA Soil Conservation Service's state and western regional offices.

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The resulting legend had single soils and soil complexes associated with the different mapping units which were based on ecological groupings of surficial deposits and vegetational communities. Bedrock types in the mapping area are similar enough so bedrock is not considered important in the determination of mapping differences.

The second stage involved use of the legend to map these soil units on the aerial photographs. Color positive photos (1:15,000 average scale) taken in the autumn and color infrared (CIR) photographs (1:50,000 scale) were used primarily. Mapping units drawn on plastic overlays of the individual photographs were transferred to 1:24,000 scale orthophotographs of the USGS topographic quadrangles. Finally, this information was transferred to USGS topographic quadrangle maps for field checking.

The area was extensively field checked in the final phase to corroborate or refute the mapping from photographs. Autumn proved to be the best time for field work because the weather is mild (few thunderstorms), there is little snow cover (easy mobility), and the Fall colors emphasize the plant communities.

The legend was continually revised as field observations dictated consolidation and splitting of mapping units. The final legend is considered to aptly characterize the soils of the area at the 1:24,000 scale, and the air photograph mapping proved to be very reliable in areas for which the proper imagery was available.

If the legend is able to be established in one field season, the second stage of air photograph interpretation can be completed during the following winter, and the third stage of field checking can be finished the next summer.

IV. THEORY BEHIND THE SOIL SURVEY LEGEND OF THE INDIAN PEAKS: ALPINE SOIL DIVERSITY AND DEVELOPMENT

I have divided the tundra into three provinces for the discussion of soil types: the high alpine which is characterized by steep alpine slopes that are mainly bedrock outcrops and talus with some thin and young soils; rolling tundra which is composed of large ridges and plateaus of the region that have gentle, rolling topography; and the glaciated valley bottoms which have soils that are formed mainly on till and scoured bedrock.

During the mapping program, it became apparent that although the alpine soils are extremely variable, there is an order to their distribution based on snow cover. A theoretical model organized around snow accumulation on the leeward side of a slope (Figure 1) was then constructed and subsequently revised many times. This Theoretical Alpine Slope has been constructed on the basis of personal observations and measurements recorded by Diane May. Table 1 describes each portion of the

slope by giving the indicator plant communities used to identify the soils and slope positions, the number of snow free days per year, and the mean annual soil temperatures at 10 cm depth. The slope has basically the same construction on the windward side as well, but generally lacks the late-lying snowbank and perennial snowbank portions as the windblown sites extend further down the slope.

The soils of the Theoretical Alpine Slope are mainly found in the rolling tundra province. Soils of the high alpine and valley bottom provinces are mapped mainly on the basis of their geomorphology. Neoglacial (last 5000 years) and late-Wisconsin (about 10,000 years B.P.) till deposits are common in the valley bottom assemblage. High alpine soils are composed of thin, moderately developed soils on the rock ledges of steep slopes with many poorly developed Entisols on talus slopes. Avalanche chutes also contain a catena of the same soils that are found on the steep slopes. Patterned ground soils are found mainly on the rolling tundra. The soils of all three provinces are listed along with their taxonomic names in Table 2.

V. PHOTOGRAPHS AND SOIL IDENTIFICATION

Various types of imagery have been used in the past to map soils, but most of the techniques have been applied in agricultural areas. Few studies have been made of alpine soils, especially in the United States. The methods presented here of using air photography to map soils in the Indian Peaks area were developed through trial and error until the most effective approach was found.

In the mountains, one has the problem that direct observation of the soil is prevented by the presence of vegetation. Landforms and vegetation are therefore used as indicators of soil conditions. These were the signatures on the photographs selected to map soils because they are the most important soil-forming factors that affect soil distribution. This is termed a deductive approach to soil mapping.

The varying durations of snow cover and the associated soil types are identified in the rolling tundra province by different vegetation communities and by landforms in the other two provinces. The plant communities are readily identified from color positive photographs (1:15,000 scale) in autumn when the changing colors differentiate the communities best. Surficial deposits are also easily identified from the photos. Photographs taken about the first week of September are found to provide the best interpretations. At this time, colors are most intense and autumn snow cover is not yet a problem. CIR photographs at the 1:50,000 scale are also useful to discern soil moisture and percentage of surface rock, both of which aid in the identification of plant communities. The CIR photographs also exhibit the greatest contrast when the photos are taken in late summer because moisture differences of the soils are

greatest.

Table 3 summarizes the signatures of the mapping units of the Theoretical Alpine Slope and its corresponding vegetational communities. (The other mapping units are not described here because they are mapped using geomorphic forms, not vegetation.

Upon consulting Table 3 one can see that at times one type of photograph is better than the other. Difficulties that arise upon using one type of photography can usually be overcome by using the other type. Discriminating between the EWB and WB sites of the Theoretical Alpine Slope on both the CIR and color positive photos is extremely difficult. These two sites are easy to discern from all of the other sites, but must be field checked for accuracy between them. The difficulty of telling the difference between these sites and the LMS site on the CIR photos is overcome by using the color positive photos where the LMS sites show up green. Telling the MSC and EMS sites from one another is difficult on CIR photographs, but it is easier on the color positive photos where yellows and reds dominate the MSC and reds and green prevail in the EMS. It is rare to find green colors outside of snowbank sites in the autumn on the color positive photos. The difference between dry willow communities of the EMS and wet willow communities of the WM can be discerned readily on the CIR whereas the colors are similar on the color positive photos. Overall, when the two types of photos are used together, they provide accurate mapping.

This study evaluated the available photographs and made recommendations for future studies. Alone, the color positive photos are more useful than the CIR in delineating the mapping units because there is less overlap in the signatures. The CIR is, in turn, found to be better than black and white photographs in identifying these different assemblages. If only one type of photograph can be obtained, the autumn color positive photographs at a large scale can provide most of the important information. For other photographs, the order of usefulness from the most useful to least useful is: CIR, color positive in mid-summer, and black and white. Satellite imagery was not examined, but there is likely lots of potential for its future use.

In this survey, soils were mapped only to the subgroup level of Soil Taxonomy. Soils could be mapped to the series level using this method if the series are established.

Fall photographs have the advantage of being taken during the season when the best weather occurs in the mountains. If satellite data is to be used to map mountain soils in the future, the autumn imagery again may be the best because the soils are the driest then and reflectance is also greatest.

VI. SUMMARY

Soil surveys above treeline are logistically difficult and very expensive. It is felt that autumn color positive and CIR photographs are very important tools that help high mountain soil surveys become more economical by reducing field work. When they are used together, the most accurate mapping can be achieved, but desirable results can also be obtained from autumn color positive photos alone.

It is hoped that these techniques will make alpine soil mapping more feasible in order to facilitate the drafting of more mountain land-use plans and thereby aid constructive management of mountain environments and reduce man's disturbances.

VII. ACKNOWLEDGEMENTS

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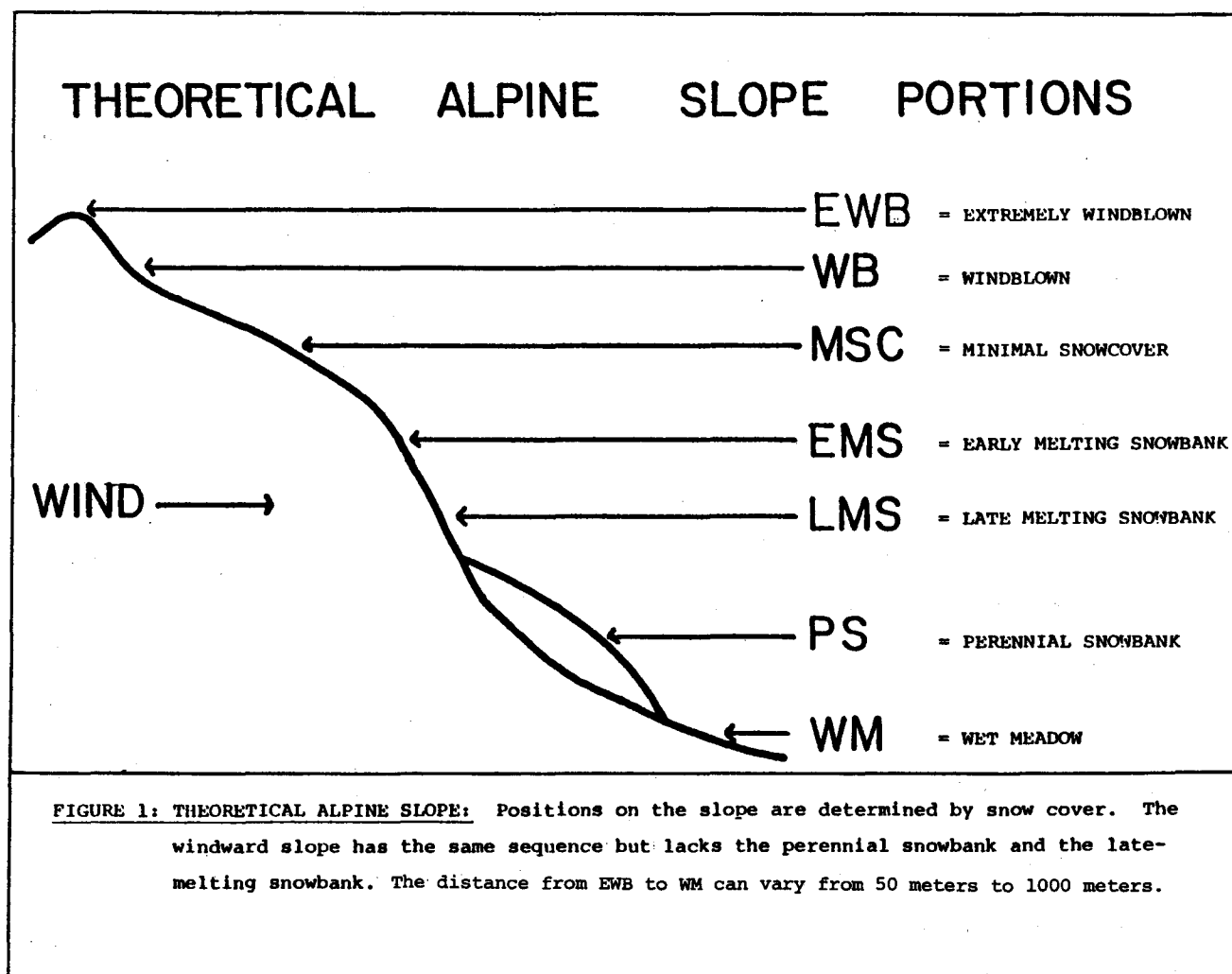


TABLE 1: CHARACTERISTICS OF THE THEORETICAL ALPINE SLOPE: The snow free days are based on personal observations and May⁹. The soil temperatures are taken from May and Webber¹⁰. The indicator plant species associated with each slope position are from Komarkova and Webber¹¹. The mapping unit numbers are those used by Komarkova and Webber¹¹ to map alpine vegetation.

Slope Position	Approximate Snow Free Days Per Year	Mean Annual Temperature at 10cm depth	Mapping Unit #	Associated Indicator Plant Species
Extremely Windblown	300	-	4	<u>Silene acaulis</u> <u>Paronychia pulvinata</u>
Windblown	225 - 300	- 0.86 °C	2, 7 5	<u>Carex rupestris</u> <u>Dryas octopetala</u>
Minimal Snow Cover	150 - 200	- 1.37 °C	6 3 1 -	<u>Kobresia myosuroides</u> <u>Trifolium dasyphyllum</u> <u>Carex elynoides</u> <u>K. myosuroides/Acomastylis</u>
Early Melting Snowbank	100 - 150	- 1.15 °C	9 10 11, 8 12, 13 20(dry)	<u>Acomastylis rossii</u> <u>Trifolium parryi</u> <u>Deschampsia caespitosa</u> <u>Vaccinium scoparium/cespitosum</u> <u>Salix planifolia/villosa</u>
Late Melting Snowbank	50 - 100	+ 1.04 °C	14, 15 16 17	<u>Sibbaldia procumbens</u> <u>Carex pyrenaica</u> <u>Juncus drummondii</u>
Perennial Snowbank	0	below 0°C	-	no vegetation
Wet Meadow	About 100	+ 0.41 °C	18,19,21 20(dry)	<u>Carex scopulorum</u> <u>Pedicularis groenlandica</u> <u>Salix planifolia/villosa</u>

TABLE 3: SIGNATURES ON PHOTOGRAPHS OF VEGETATIONAL COMMUNITIES OF THE THEORETICAL ALPINE SLOPE IN THE AUTUMN: Numbers of the associated plant communities are taken from Table 1 and are the Mapping unit numbers used by Komarkova and Webber¹¹. Please note that the photograph colors may vary because of variation in the exposure, type of film used, and the varying developmental techniques.

Slope Position	Plant Community Mapping Unit #	Color Positive Color In the Autumn	CIR Color in the Autumn
Extremely Windblown	4	gray tan	gray
Windblown	2,5,7	tan	gray
Minimal Snow Cover	1,6 3, 6/9	golden yellow red brown & yellow	reddish gray reddish gray
Early Melting Snowbank	8,9,10,11,12,13 20(dry)	red brown & green dark brown	grayish red grayish red
Late-melting Snowbank	14,15,16,17	green	gray
Perennial Snowbank	none	white	white
Wet Meadow	18,19,21,20(wet)	dark brown	deep red

TABLE 2: Alpine soils mapped in the Indian Peaks region of the Colorado Front Range

<u>MAPPING UNIT NAME</u>	<u>TAXONOMIC NAME</u>
1) Extremely Windblown Soil	1) Dystric Pergelic Cryochrept
2) Windblown Soil Complex	2) Pergelic Cryochrept Dystric Pergelic Cryochrept
3) Minimal Snow Cover Soil Complex	3) Pergelic Cryumbrept
4) Early Melting Snowbank Soil Complex	4) Typic Cryumbrept Pachic Cryumbrept
5) Late-Melting Snowbank Soil	5) Dystric Cryochrept
6) Perennial Snowbank Soil Complex	6) Lithic Pergelic Cryorthent Pergelic Cryoboralf over a buried Pergelic Cryoboralf
7) Wet Meadow Soil Complex	7) Histic Pergelic Cryaquept Pergelic Cryaquept
8) Soil on Patterned Ground	8) Pergelic Entic Cryumbrept
9) High Alpine Steep Soil Complex and the Avalanche Chute Soil Complex	9) Pergelic Cryorthent Lithic Pergelic Cryochrept Dystric Pergelic Cryochrept Lithic Pergelic Cryoboroll
10) Late-Wisconsin Surficial Deposit Soil	10) Dystric Pergelic Cryochrept
11) Neoglacial Surficial Deposit Soil	11) Pergelic Cryorthent